ANALYTICAL X-RAY SAFETY

This policy:

1. Establishes general requirements for analytical x-ray equipment at Ames Laboratory based on current American National Standard Institute (ANSI) Standard N43.2 and the Ames Laboratory Radiological Protection Program.
2. Defines responsibilities, specific authorization of users, and requirements for x-ray machine operation and maintenance.
3. Outlines user-training requirements.

Comments and questions regarding this policy should be directed to the contact person listed below:

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Sign-off Record:

Approved by: _____ Date: _____
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Approved by: _____ Date: _____
Manager, Engineering Services Group

Approved by: _____ Date: _____
Manager, ESH&A Office

Approved by: _____ Date: _____
Laboratory Deputy Director

1.0 Revision/Review Log

This document will be reviewed every three years as a minimum.

Revision Number	Effective Date	Contact Person	Pages Affected	Description of Revision
0	7/1/94	Hokel	All	Initial Issue
1	3/1/98	Hokel	All	Periodic
2	10/1/99	Hokel	All	Update/correction
3	01/10/00	Hokel	All	Review
4	07/15/01	Beckel	All	G:\Docs&Recs\DCP\RevisionDescription\Policy10202_3rev4

2.0 Purpose and Scope

2.1 Purpose

The purpose of this policy is to keep radiation exposures from analytical x-ray systems as low as reasonably achievable (ALARA). This policy promotes the radiation safety guidance specified in American National Standards Institute (ANSI) Standard N43.2, "Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment", and referenced standards therein, in addition to applicable portions of the Ames Laboratory Radiation Protection Program (RPP).

2.2 Scope

This policy ensures that guidelines and/or regulations specific to the radiation safety aspects of the design and operation of x-ray diffraction and fluorescence analysis equipment are implemented uniformly throughout the Laboratory.

3.0 Prerequisite Actions and Requirements

3.1 Definitions

ALARA (As Low As Reasonably Achievable)*:* An approach to radiological control to manage and control exposures (individual and collective) to the work force and to the general public at levels as low as is reasonable, taking into account social, economical, technical, practical and public policy considerations.
Analytical X-ray Equipment*:* Equipment used for x-ray diffraction or fluorescence analysis.
Analytical X-ray System*:* A group of components utilizing x or gamma rays to determine the elemental composition or to examine the microstructure of materials.
Barrier: A physical object that restricts access to the primary x-ray beam.
***Controlled Area*:** An area to which access is controlled in order to protect personnel from exposure to radiation from analytical x-ray systems. This area is normally the x-ray laboratory and is under the supervision of the group leader. Personnel must have a minimum of General Employee Radiological training to enter a controlled area.
Exposure*:* A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all of the ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.
Exposure Rate*:* The exposure per unit of time.
***High Radiation Area*:** Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (0.001 Sv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
***Interlock*:** An electronically controlled switch, which causes an interruption in the primary x-ray beam when part or all of the barrier around the system is moved.
Leakage Radiation: All radiation coming from the source housing except the useful beam.
Local Components*:* Part of an x-ray system and includes areas that are struck by x-rays, such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors, and shielding, but does not include power supplies, transformers, amplifiers, readout devices, and control panels.
Normal Operation*:* Operation under conditions suitable for collecting data as recommended by a manufacturer of the x-ray system. Recommended shielding and barriers shall be in place.
Open-beam Configuration*:* An analytical x-ray system in which an individual could accidentally place some

part of the body in the primary beam path during normal operation or during alignment operations when the x-ray beam is on and individuals could place part of the body in the primary beam.
Personnel Dosimetry: Devices designed to be worn by a single person for the assessment of dose equivalent such as film badges, whole body or extremity thermo luminescent dosimeters (TLDs), and pocket ionization chambers.
Primary Beam: Ionizing radiation from an x-ray tube anode which is allowed to pass by direct path through an aperture in the radiation source housing for use in conducting x-ray measurements.
Rad: The unit of absorbed dose. One rad is equal to an absorbed dose or 100 ergs per gram or 0.01 joules per kilogram (0.01 gray).
Radiation Area: An area, accessible to personnel, in which radiation levels could result in a person receiving a whole body dose equivalent in excess of 5 mrem (50 uSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.
Radiation Survey: An evaluation of the radiation hazard potential associated with a specified set of conditions incident to the production, use, release, storage, or presence of radiation sources.
Radiological Buffer Area (RBA): An intermediate area established around each analytical x-ray system to protect personnel from radiation exposure. Entry requires a minimum of Radiological Worker I training.
Rem: Unit of dose equivalent. Dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by a quality factor, distribution factor, and any other necessary modifying factor (1 rem = 0.01 sievert).
Scattered Radiation: Radiation that, during its passage through a substance, has been changed in direction. It may also have been modified by a decrease in energy.
Stray Radiation: The sum of leakage and scattered radiation.
Useful Beam: Radiation, which passes through an aperture, cone, or collimating device of the x-ray source, housing; commonly referred to as the "primary beam."
X-rays: Penetrating electromagnetic radiations whose wavelengths are shorter than those of visible light. Bombarding a metallic target with fast electrons in a high vacuum usually produces them.
X-ray Generating Equipment: All apparatus used to produce x-rays, including: the high voltage generator, x-ray tube housing, and associated electrical connections.
X-ray Installation: One or more x-ray systems, the surrounding room or controlled area, and the installation enclosure.
X-ray System: Apparatus for generating and using ionizing radiation in the form of x-rays, including: x-ray generating equipment, diffractometers, cameras, and film.

3.2 Relationship of this policy to ANSI N43.2 and the RPP.

This policy is based entirely on ANSI N43.2 and the Ames Laboratory RPP. Should a conflict arise between the requirements of this policy and the ANSI Standard or the RPP, the requirements of the ANSI Standard and RPP shall be deemed superior to this policy.

3.3 Roles of Key Personnel

3.3.1 Ames Laboratory Senior Management – Ames Laboratory senior management has established high standards for performance of analytical x-ray safety. These standards and management expectations have been frequently communicated to the x-ray users. Senior management is committed to an x-ray safety program of highest quality, and has demonstrated their strong commitment to and support of the program by allocating sufficient resources such as funding, personnel, and training.

3.3.2 Program Director/Department Manager -- The Program Director shall be responsible for the following:

- Ensure that radiation safety requirements set forth in ANSI N43.2 and applicable portions of the RPP are being carried out.
- Ensure the requirements of this policy and the requirements and procedures stated in ANSI N43.2 have been implemented in their program areas

3.3.3 Group/Section Leader -- Group/Section Leaders are responsible for adequate control of analytical x-ray hazards under their supervision. The radiation hazards may be to employees, visitors, and/or the general public. Group/Section Leaders shall establish practices and procedures for operation of the x-ray systems in their areas that are consistent with the intent of this policy and requirements of ANSI N43.2

- Initiation of the Readiness Review, as appropriate, for any of the following actions for analytical x-ray systems:
  - Initial installation of an x-ray system, whether in an existing or new area;
  - Modification of an x-ray system that alters the hazards associated with its use.
- Issuance of appropriate instructions and training materials on potential radiation hazards and their control to all personnel under their supervision;
- Ensuring that employees and visitors have the proper personnel dosimetry;
- Ensuring that all analytical x-ray users complete required radiation training;
- Maintaining copies of the following documents that will be readily available to operators:
  - ANSI N43.2;
  - The approved Group/Section's Standard Operating Procedures for the analytical x-ray system;
- Know where to obtain access to other useful x-ray safety information.

3.3.4 Safety Representative -- The Safety Representative serves as a liaison between Group Leaders and x-ray users to ensure Ames Laboratory policies and procedures for x-ray safety are being carried out and to bring items of concern from users to the attention of management. The Safety Representative should be familiar with the operational aspects of all x-ray devices that are used by the program. This person will also serve as the point of contact to coordinate safety issues concerning maintenance and repair activities as well as radiation safety issues brought forth by the ESH&A Office.

3.3.5 Analytical X-ray System Users -- Users of analytical x-ray systems at Ames Laboratory shall be responsible for the following:

- Compliance with radiation safety policies & procedures;
- Thorough understanding of the x-ray system(s) used and all necessary safety considerations associated with such use, as well as what to do in an emergency situation;
- Obtaining the required training to operate analytical x-ray systems at Ames Laboratory;
- Being familiar with and adhering to the applicable x-ray safety standards;
- Prompt reporting of any known or suspected radiation exposure, accidents involving personal injury or incidents which cause significant damage to Laboratory equipment or facilities;
- Wearing appropriate personnel dosimetry whenever operating the analytical x-ray system;
- Recording all uses of x-ray systems in the logbook and report all unusual or potentially unsafe conditions to their supervisor.

3.3.6 ESH&A Office -- ESH&A Office will assist in performing Readiness Reviews of existing systems, modifications to existing systems, or new installations. In addition ESH&A OFFICE health physics personnel will ensure that appropriate radiation dosimetry is assigned to x-ray system users and provide quarterly notification for exchange of the dosimetry. Employees shall not be permitted to operate an x-ray system, until they have received appropriate training for analytical x-ray use and have been issued radiation dosimetry. The Radiation Safety Officer (RSO) will perform periodic safety inspections of the x-ray systems and report the

results to group leaders.

3.3.7 Engineering Services Group (ESG) – ESG shall conduct semi-annual verification of proper operation of engineered safety systems, as required by section 8.7 of ANSI N43.3, which states: "All shields, interlocks, and other safety devices shall be inspected periodically and *appropriately serviced* as scheduled by the radiation protection supervisor. The interval between inspections shall not exceed six months." Records of semi-annual verifications shall be forwarded to the ESH&A Office Health Physicist.

3.4 Training

3.4.1. Analytical X-ray Safety Training – AL-076

All Ames Laboratory employees wishing to use x-ray systems will complete Ames Laboratory training or Iowa State University equivalent training on analytical x-ray. "Radiological Worker Training for Users of Analytical X-ray Systems, AL-076" is available from the ESH&A Office. Iowa State University X-ray Safety Training, #RAM03, is available from EH&S.

3.4.2. Radiation Survey Instrument Training – AL-157

All personnel shall receive instructions from the ESH&A Office Health Physics Section on the proper operation and use of radiation survey instruments that are provided to users in analytical x-ray laboratories. This brief, hands-on training period shall be provided as soon as possible after the personnel complete the x-ray training specified above. No personnel shall operate analytical x-ray systems without completing Analytical X-ray Safety Training, AL-076, receiving job specific training, and receiving their dosimetry. In addition, employees being issued new dosimetry shall complete Radiation Survey Instrument Training, AL-157, prior to ESH&A delivering dosimetry.

3.4.3. Electrical Safety Program – AL-019, AL-020

Analytical x-ray system users who may have occasion, in the course of performing their work, to encounter live energized parts, must attend the appropriate electrical safety training module as described in the Electrical Safety Manual. Employees who pass electrical safety training, receive proper additional job specific training, and group/section leader approval, shall be considered "qualified electrical workers".

Only qualified electrical workers shall repair or perform maintenance on x-ray high voltage equipment. Interlocks designed to protect from electrical hazards shall not be bypassed, unless by qualified electrical workers when inspecting, adjusting, or working on the equipment. Proper procedures shall be followed when bypassing electrical safety interlocks.

3.4.4. Job (Activity) Specific Training

For training on specific analytical x-ray systems, Group Leaders will designate a person from their group who is experienced in the operation of the system(s) to provide (instruction) - Job (Activity) Specific Training - to other employees who will work on the systems. This training shall include as a minimum:

- operation of the system and associated safety procedures;
- emergency procedures;
- basic radiation hazards associated with the system;
- proper use of personnel dosimetry devices;
- safe work practices;

- use of survey instruments;
- the function of safety features on the system such as warning lights and barrier interlocks.

The information found in Section 4.1, "Practices and Guidelines", of this policy may be useful in conducting this training. An Electrical Safety Program Training or Retraining statement, form 46200.009 shall be signed by both the employee and the Group Leader or designated trainer and will be maintained in the employee's training record in the ESH&A training department. A user must be recertified to operate the equipment whenever they have not used the machine for a period in excess of one year or at the discretion of the Group Leader or his designee.

4.0 Analytical X-ray Safety Policy

4.1 Practices and Guidelines

4.1.1. Standard Requirements for Analytical X-ray Areas

One or more of the following features shall be employed for each entrance or access point to a high radiation area, (i.e., the area immediately around the x-ray port) where radiation levels exist such that an individual could exceed a deep dose equivalent to the whole body of .1 rem (0.01 sievert) in any one hour at 30 centimeters from the source or from any surface that the radiation penetrates:

(1) A control device that prevents entry to the area when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a high radiation area;
(2) A device that functions automatically to prevent use or operation of the radiation source or field while individuals are in the area;
(3) A control device that energizes a conspicuous visible or audible alarm signal so that the individual entering the high radiation area and the supervisor of the activity are made aware of the entry;
(4) Entryways that are locked. During periods when access to the area is required, positive control over each entry is maintained;
(5) Continuous direct or electronic surveillance that is capable of preventing unauthorized entry;
(6) A control device that will automatically generate audible and visual alarm signals to alert personnel in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the area or activation of a secondary control device that will prevent use or operation of the source.

10 CFR 835 requires that personnel dosimetry shall be provided to and used by individuals entering a high or very high radiation area. In the case of analytical x-ray systems, high and very high radiation areas could be encountered at or near the x-ray port, therefore, ring dosimetry must be worn at all times when operating these systems.

The primary objective in devising and implementing analytical x-ray control measures is minimizing the potential for radiation exposure, especially from the primary x-ray beam. To this end, Ames Laboratory requires that all analytical x-ray systems at Ames Laboratory be operated only in approved areas. The following are standard requirements for Ames Laboratory analytical x-ray system usage areas:

4.1.1.1 *Posting and Labeling*

Entry doors to analytical x-ray laboratories shall be posted with "Controlled Area" signs.

A Radiological Buffer Area (RBA) boundary shall be established around each analytical x-ray system in a laboratory, and the RBA shall have the same boundaries as the physical interlocked barrier around each

system. The RBA will limit access to those personnel who are properly trained and who require entry for purposes of using the x-ray system. Each RBA shall be posted with a RBA warning sign, or statement, which is clearly readable by all persons who enter the laboratory.

4.1.1.2 *Non-essential equipment*

Equipment not utilized in analytical x-ray experiments should not be located within the same room. If it is impractical to relocate such equipment, operation of the equipment shall be minimized as much as practical and shall in no case interfere with the safe operation of x-ray equipment in the room. Personnel who work in the same room in which an analytical x-ray system is located are not authorized to enter the Radiological Buffer Area to conduct activities and must have General Employee Radiological Training, since they will be working in a Controlled Area.

4.1.1.3 *Instrumentation*

There shall be a radiation detection instrument of the appropriate energy response located in the immediate working area of all analytical x-ray systems at Ames Laboratory. Group Leaders shall ensure that periodic checks are made near the x-ray system to detect stray radiation. Before use checks shall be made to make sure the instrument is functioning properly. The ESH&A Office will provide the instruments and ensure they are calibrated annually.

Area monitors are *recommended*, but not required, for laboratories in which there is one or more open beam system. Area monitoring devices are available from the ESH&A Office upon request. Installation is the responsibility of the Group.

4.1.1.4 *System Barrier*

All open beam analytical x-ray system shall have an enclosure housing and accessory equipment enclosure that meets all of the requirements of ANSI N43.2 and shall be interlocked such that all shutters will close if access doors are opened, unless the interlock is consciously defeated.

4.1.1.5 *Multiple X-ray Systems within A Single Laboratory*

When two or more analytical x-ray systems are located within a single laboratory and are not part of the same experiment, they shall be set up in such a way that they may be independently and simultaneously operated as if each were in its own laboratory. Specifically, primary x-ray beams and leakage radiation shall be confined to within a single experimental area. All x-ray systems within one Controlled Area may be located in the same RBA, if practical.

4.1.2. Specific Hazard Awareness

Analytical X-ray System Supervisors or Group Leaders shall not permit operation of a new or modified x-ray under their authority without making personnel aware of the potential hazards associated with the use of each type of system in their area. This "awareness training" must be documented and shall be made part of any Readiness Reviews for new or modified systems.

4.1.3. Standard Operating Procedures

Standard Operating Procedures shall be written for each analytical x-ray system. (See Attachment 1 for guidance).

4.1.3. Personnel Radiation Monitoring

The most likely areas of the body to receive a dose from analytical x-ray work are the extremities. For this reason, all analytical x-ray users are required to wear *extremity* (ring-type) personnel dosimetry at all times when working with the systems. The dosimetry will assess each worker's external radiation exposure to the extremities from x-rays. Part 4.5.2 of the RPP, "Individual Monitoring", requires the use of personnel monitoring for analytical x-ray users, including declared pregnant women.

The ESH&A Office will exchange dosimeters quarterly and will maintain records of monitoring results. Questions regarding your individual monitoring records may be directed to the ESH&A Office Health Physics personnel at 4-7926 or 4-7922 at any time. If there is reason to suspect that a worker has received an exposure, the worker's supervisor should be notified immediately, as well as the ESH&A Office Health Physics Group at one of the two telephone numbers above.

4.1.4 Declared Pregnant Women

Group leaders must inform all female employees, before they start working with analytical x-ray systems, of the RPP requirements concerning pregnant women. The RPP states that:

- Pregnant women may voluntarily declare to her employer (Ames Lab), in writing, her pregnancy for the purpose of being subject to the occupational dose limits to the unborn child as specified in 10 CFR 835.206 and Table 2-1, Ames Laboratory Site-Specific Radiological Control Manual (AL SSRCM). This declaration may be revoked, in writing, at any time by the declared pregnant worker;
- The maximum allowable dose limit to an unborn child shall be maintained at less than 0.5 rem from conception to birth as a result of occupational exposure of a declared pregnant woman.

4.2 Records

Required records include: training, system users, system use and records of maintenance on the system. These records may either be kept in separate books called a "User Logbook" and a "Maintenance Logbook", or they can be combined and kept in one book in separate sections. Computerized records are authorized and shall be readily retrievable, accurate and appropriately archived. All records shall be current to the present day of operation and be kept near the system.

It is recommended that the logbook or computer record contain the following information:

- Name of person performing maintenance on system and employer if outside contractor;
- The reason the maintenance was performed;
- Specific problems noted during maintenance;
- Repairs performed (if a modification to the system is performed, reference the date of approval from Group Leader and the ESH&A Office);
- Time and date the maintenance was performed; and

- Signature of the person who did the maintenance on the system (**NOTE**: this signature indicates certification that the system is in proper working condition, including all barrier interlocks, warning lights, and fail-safe devices. It also means that all circuitry and construction associated with the system, including any and all approved modifications to the system, are in full compliance with the manufacturer's specifications and the requirements of ANSI N43.2.). Computer records shall be signed appropriately when printed from record.

4.3 Shielding

All x-ray-generating systems shall have adequate shielding to minimize stray radiation so that exposures to employees can be kept ALARA.

4.4 Environment, Safety, Health & Assurance Radiation Safety Inspections

The ESH&A Office will conduct surveys of the x-ray systems approximately once each year on systems that are actively in use. Results of these inspections will be reported to the Group Leader and Program Director.

The ESH&A Office will review and approve new installations in accordance with the policy and procedures of the Activity Review process.

4.5 Variances

Exceptions to the general safety procedures for specific operational cases may be granted. The operator must submit a written request for a variance to the ESH&A Office. This request will then be processed in accordance with procedures of the Activity Review process. If approved by the Activity Review, a written variance will be issued and must be kept with the system's logbook.

5.0 Additional Information

5.1 References

- American National Standards Institute, ANSI N43.2-1977, Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment.
- American National Standards Institute, ANSI N43.3-1993, Installations Using Non-Medical X-ray and Sealed Gamma-Ray Sources, Energies up to 10 MeV.
- Ames Laboratory Radiological Protection Program.
- 10, Code of Federal Regulations, Part 835, "Occupational Radiation Protection", most current revision.

5.2 Attachments

- Attachment 1: Guide for Writing Standard Operating Procedures.

ATTACHMENT 1
GUIDE FOR WRITING STANDARD OPERATING PROCEDURES

The following is guidance for writing a Standard Operating Procedure (SOP). Note that the examples of hazard controls listed below may or may not be applicable to your usage area. Your SOP should address specific hazards (and appropriate measures used to control them) in your area(s).

1. Include a signature page as the first page. Following the signature page, date and number the pages.

2. List those authorized to use the x-ray system(s) or include statements such as:
   - Only those specifically authorized by (insert name of individual supervising this x-ray system) are to be permitted to operate the x-ray system(s) within this area.
   - Visitors shall be trained in accordance with the procedures specified in Ames Laboratory Procedure "Visitor Training."

3 State the ionizing radiation hazard(s) that exist in the area including x-ray energy or power, hazardous areas within the area, etc.

4 State any other hazards associated with the x-ray system such as high voltage, compressed gases, toxic chemicals, etc.

5. List the measures used to control radiation hazards other than those directly associated with alignment of the x-ray beam. Normally these include radiation hazard warning signs, hazard warning lights, and interlocked barriers around the systems, which activate a beam shutter or equivalent on entry of unauthorized personnel into the High Radiation Area. Some examples of other administrative and procedural control measures include:
   - The radiation hazard warning light system at entrance(s) to the interlocked barrier (High Radiation Area) shall be maintained in good operating order and shall be tested quarterly by the supervisor of this area to ensure good working order. Such inspections shall be documented in the logbook.
   - As much of the x-ray beam path and leakage radiation as practical shall be contained. Use only appropriate shielding in achieving containment.
   - The barrier interlock defeat switch shall be used only by authorized x-ray system users and then only when it is essential to avoid interruption of an experiment or to perform x-ray beam alignments.

6. In writing your SOP, emphasize any unusual potential hazards of the x-ray area and the methods used to control such hazards. Examples of such hazards include:
   - Areas where it is not possible to shield the x-ray beam adequately;
   - Operation and maintenance of the x-ray system by more than one group;
   - The presence of equipment within the area that is not utilized in analytical x-ray experiments. The hazard is acute when such equipment must be operated by other than an authorized x-ray user.